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PERFORMANCE CHARACTERISTICS OF LITHIUM PRIMARY BATTERIES.(U)
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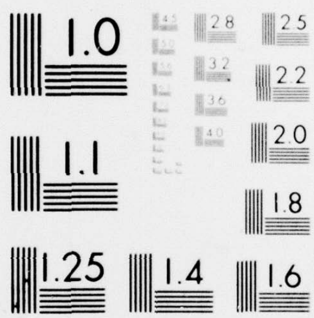

MICROCOPY RESOLUTION TEST CHART
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Lithium Battery Session

PERFORMANCE CHARACTERISTICS OF LITHIUM PRIMARY BATTERIES

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Lithium-organic electrolyte primary battery programs have been under active development at ECOM for the past four years. To date a few practical lithium-organic electrolyte systems have emerged from this effort.

The most promising of these is the lithium-sulfur dioxide system. This system has an open circuit voltage of 2.95 volts and is capable of operation from −40°F to 125°F. Figure 1 shows typical discharge characteristics of a "D" cell at a resistive load of 10 ohms at various temperatures. The cell is nominally rated at a 10 ampere-hour capacity. The curves are considered typical for the lithium sulfur dioxide system, obtaining about 60% capacity at −40°F and approximately 70% at −20°F discharges. Maximum voltages are depressed with temperature from 2.75 volts at 125°F to 2.35 volts at −40°F under the 10 ohm discharge rate. Of significance is the service time of the 125°F discharge being lower than the 75°F discharge. This decrease in service time is due to

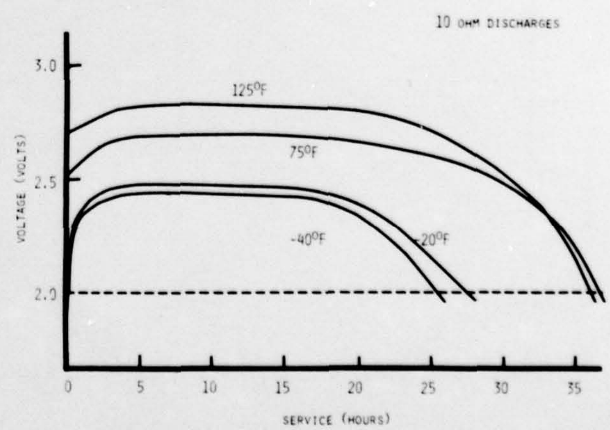

Figure 1. Lithium-Sulfur Dioxide "D" Cells Discharged at 10 Ohms.

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the fact that discharge at 125°F takes place at a higher voltage, current and wattage level.

Figure 2 displays a log-log plot of lithium sulfur dioxide

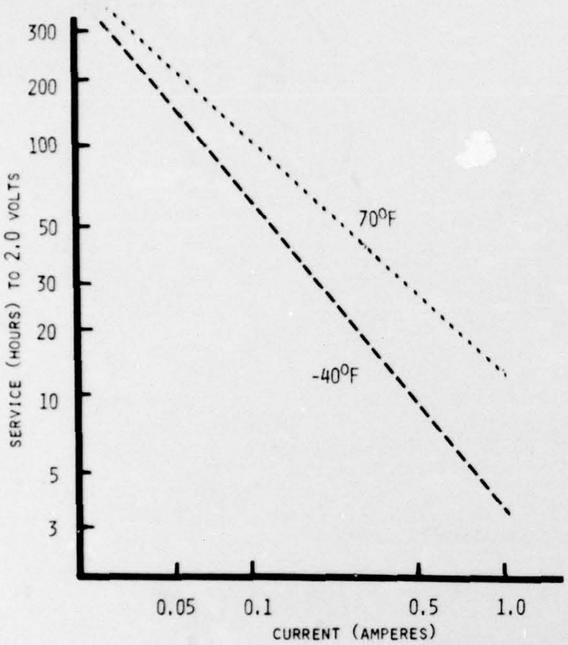

Figure 2. Lithium-Sulfur Dioxide "D" Cells—Service Vs Current from —40°F to 70°F.

"D" cells[1] showing service versus current at temperatures of —40°F and 70°F. This plot shows that the relative difference in service hours increases at the higher current rates.

In Figure 3 the energy density of the lithium sulfur dioxide system[1] is plotted at various temperatures and discharge rates. As can be seen, the energy densities range from

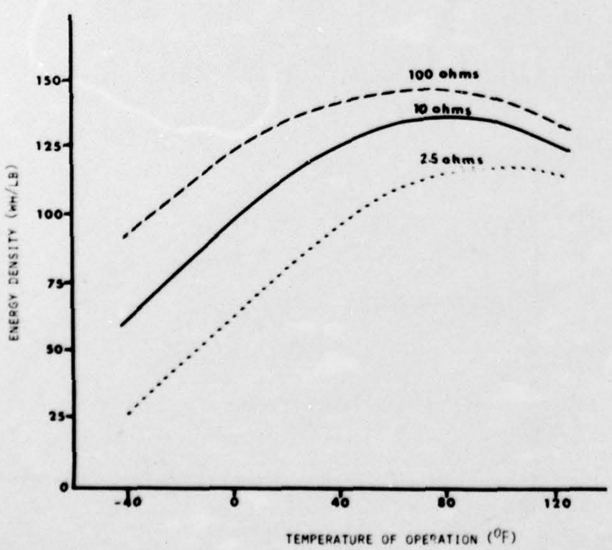

Figure 3. Energy Density of the Lithium-Sulfur Dioxide System at Various Temperatures and Discharge Rates.

a high of 140 Wh/lb for the 100 ohm rate at 80°F to approximately 25 Wh/lb at —40°F at the 2.5 ohm rate to a cutoff of 2 volts per cell.

The lithium sulfur dioxide system in the spiral wrap configuration has one of the lowest internal resistances known when compared to other lithium organic systems. It is approximately 0.1 ohm for a "D" cell configuration. This, of course, makes it ideal for providing high current pulses, particularly at the lower temperatures without going below the minimum voltage normally specified. The maximum energy density for this system is obtained at 3-4 mA/cm^2 or below.

Associated with the sulfur dioxide system is a "delay" (time to reach cutoff voltage of 2.0 volts at the start of a discharge) which is particularly noticeable after long term high temperature storage and at high rate discharges at low temperatures. The delay for heavy rates at —20°F is normally under five seconds. This delay is attributed to a film formed on the anode which rapidly dissipates during the initial moments of discharge. This film, once removed, does not readily reappear; hence a discharge may be interrupted for a few days without a delay recurring when the discharge is resumed.

The lithium sulfur dioxide system has been used with excellent results as a communication type battery. Figure 4

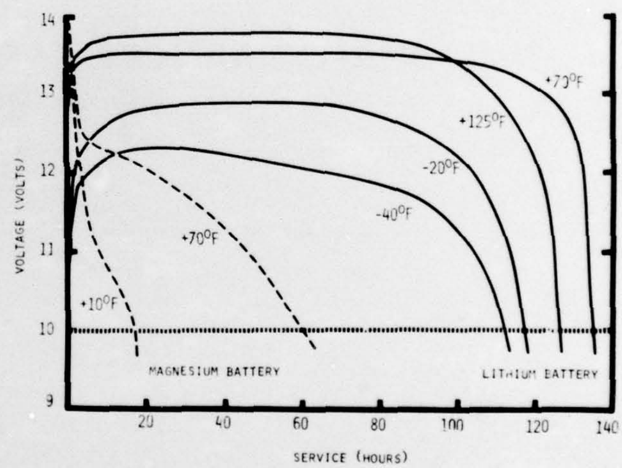

Figure 4. Comparison of Lithium Battery Vs Magnesium Battery.

illustrates the superior performance of the lithium Battery BA-5386( )/U at various temperatures compared to the magnesium Battery BA-4386( )/U. Battery BA-5386( )/U, weighing approximately 2.6 pounds, has a complement of 10 "D" type cells (5 series, 2 parallel arrangement). Battery BA-4386( )/U has a total of 16 long "C" type cells (8 series, 2 parallel arrangement) and weighs approximately 3 pounds. The discharge loads were applied on the following cycle:

Two (2) minutes — transmit — 14.7 ohms

Eighteen (18) minutes — receive — 290 ohms

Figure 4 is the discharge curve during the transmit phase, the more severe condition and the one which limits service life.

Of particular interest is the performance of the lithium battery at the low temperatures. Normal transportation, shock,

and vibration had no effect on the performance of these batteries.

Data on long term storage of batteries employing the lithium-sulfur dioxide system are still limited and shows this system to have erratic performance. Quality control on batteries made prior to and during the early part of 1973 was considered poor. While many batteries showed normal performance on initial tests, a number failed shortly after being subjected to 130°F and 160°F storage. The best 130°F storage data were obtained with Battery BA-5546( )/U, manufactured in late 1971, although it showed variability in battery-to-battery performance. This is a 24-volt battery containing a complement of 10 "C" size cells of about 3.5 Ah capacity. Table I presents the storage data giving the two

TABLE I

130° F STORAGE ON LITHIUM-SULFUR DIOXIDE BATTERY BA-5546( )/U

DISCHARGE LOAD OHMS	SERVICE HOURS AFTER 130°F STORAGE							
	NO STORAGE		6 MO		9 MO		12 MO	
25	1.9	1.8	1.7	1.6	1.7	1.5	1.7	F*
50	4.6	4.5	4.1	4.5	4.0	3.7	3.8	2.2
100	10.5	11.3	10.3	10.0	9.4	8.6	8.1	8.1

ROOM TEMPERATURE DISCHARGE

*FAILED ON CLOSED CIRCUIT VOLTAGE

results obtained under each test condition. The data indicates relatively good retention of initial capacity after 12 months storage at 130°F when discharged at a resistance of 25 to 100 ohms.

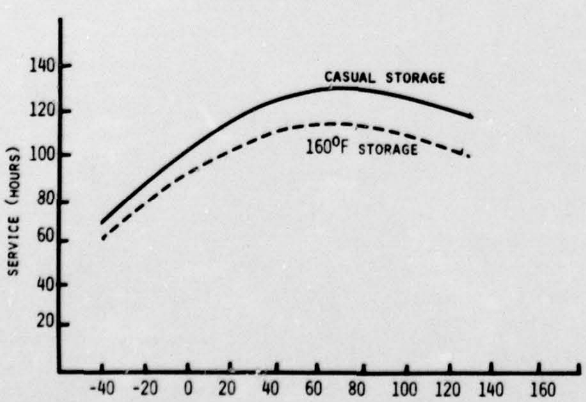

Figure 5. Comparison of BA-5386( )/U Capability after 1 Month Storage at 160°F Vs Casual Storage.

Figure 5 presents a comparison of the performance of Batteries BA-5386( )/U (manufactured December 1973) after 1 month storage at 160°F and 4 month casual storage. The batteries were discharged at the normal BA-5386( )/U loads described above. Figure 5 shows performance under the transmit load. The test results indicate a maximum loss of approximately 15-20% in capacity after one month exposure at 160°F.

The second most promising lithium-organic electrolyte system is the carbon monofluoride system. This system has an initial voltage of between 2.9 and 3.1 volts and delivers an energy density of 60 to 140 Wh/lb at room temperature, depending on the rate of discharge. The system is capable of operating over a temperature range of −20°F to 140°F. Some cells have demonstrated a good storage capability with a loss of 10-15% in capacity after one month storage at 160°F, or on the other extreme, some are complete duds after this storage. Maximum energy density performance is obtained with current densities of 3 mA/cm². The cutoff voltage of this system is approximately 1.67 volts. In order to build a 24 volt battery, 11 or 12 lithium-carbon monofluoride cells are required as compared to only 10 cells for the lithium sulfur dioxide system. As this battery system is still being developed and designs and formulations have not been optimized, the test results vary depending upon the particular approach taken by each manufacturer.

The delay problem noted with lithium-sulfur dioxide system also exists with the lithium-carbon monofluoride system. Delays have been experienced chiefly at the higher rates, 1 ampere to 100 milliamperes, particularly at the lower temperatures after storage at high temperatures where delays noted were up to a few seconds in duration. The internal resistance of a "C" size lithium-carbon monofluoride cell, even with the spiral wound construction, is relatively high, having a value somewhere in the order of 0.4 to 0.7 ohms. However, at the lighter loads (10 mA), performance at −20°F is almost 80% of room temperature capacity.

Figure 6 shows the typical discharges, at various tem-

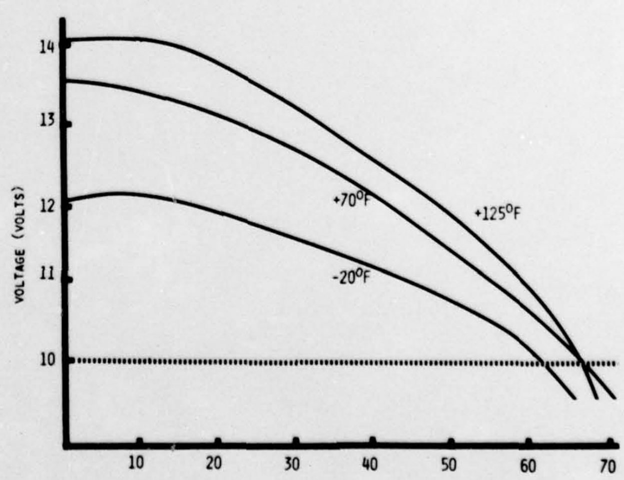

Figure 6. Performance of Lithium-Carbon Monofluoride System in the Half-Size BA-5386( )/U Configuration.

peratures, of a lithium-carbon monofluoride system in the half-size BA-5386( )/U battery configuration. (This battery consists of 12 long "C" size cells).

In summation, two practical lithium organic electrolyte systems have emerged from the past four years of development activity. Certainly the performance of the lithium-organic cells, particularly at the temperature extremes, is outstanding compared to other present day primary systems. While the results can be considered most promising, certain areas, such as reducing variability and increasing reliability, require further effort before the lithium-organic electrolyte battery can be considered fit for military field use.

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